General Improvements to Signalized Intersections

The Massachusetts Department of Transportation (MassDOT) has performed a safety evaluation of the improvement of 34 signalized intersections (21 4-leg and 13 3-leg) throughout the Commonwealth. These intersection improvements included signal equipment and timing upgrades, pedestrian, bicycle, and ADA improvements, pavement resurfacing, and signage and pavement marking upgrades. Some intersections were also treated with adding protected/permitted or protected left-turn phasing and the addition of left and/or right turn lanes. Figures 1 and 2 provide an example of the changes at one of these intersections. The intention of this evaluation was to estimate a Crash Modification Factor (CMF) to understand the safety effectiveness of these improvement projects, along with an economic evaluation at the intersections. Results indicated that multi-vehicle crashes were reduced by 19%, multi-vehicle fatal and injury (FI) crashes were reduced by 33%, and angle crashes were reduced by 37%. **It is anticipated that a $1 million investment in this treatment is expected to prevent 16 possible-injury crashes and 7 fatal, incapacitating, or non-incapacitating injury crashes over a 20 year period.**

Figure 1 - The intersection of Belmont Street with Shrewsbury Street in Worcester, MA, before the improvements [Google Earth, 2009]

Figure 2 - The intersection of Belmont Street with Shrewsbury Street in Worcester, MA, after the improvements [Google Earth, 2016]

Background

In MassDOT's 2013 Strategic Highway Safety Plan, intersections were identified as an emphasis area for safety improvement. Intersections were also called out for improvement, along with left turn crashes, as part of MassDOT's 2016 Highway Safety Improvement Program (HSIP). The study intersections were identified for improvements based on operational issues, crash history, and accessibility issues. The study intersections were both individual intersection projects and parts of corridor improvements.

The many improvements made to these intersections should lead to a reduction in multi-vehicle crashes. Improvements to operations, mainly done by updating signal equipment, phasing, and timing, should reduce angle crashes and rear end crashes. The accessibility improvements, accomplished via higher visibility crosswalks, improved pedestrian signals, pavement markings and signage for bikes, and enhanced pedestrian phasing, should lead to a reduction in pedestrian and bicycle crashes. The resurfacing and upgraded signage and pavement markings should also reduce crashes by improving visibility to the drivers and providing better friction for braking vehicles.

Results

The empirical-Bayes before-after methodology was used to estimate CMFs for these intersection improvements. A total of 34 urban/suburban arterial intersections, including 21 4-leg intersections and 13 3-leg intersections, were analyzed, with an average of 3.6 before-years and 3.1 after-years per site. Prior to the

conversion, there were a total of 789 multi-vehicle crashes (191 FI and 598 property-damage only [PDO]), 301 angle crashes (94 FI and 207 PDO), and 353 rear end crashes (78 FI and 275 PDO). Along with angle and rear end crashes, multi-vehicle crashes also consisted of sideswipe and head-on crashes.

The samples of 3-leg intersections and 4-leg intersections were initially evaluated separately, but the similarity in results led to the two samples being combined for an overall evaluation. The summary of the significant findings, along with their standard errors (SE), can be found below in Table 1. Spaces marked with X indicate that the finding was not statistically significant at the $\alpha = 0.05$ level. Note that a crash reduction as a result of a treatment is equal to 1 minus the CMF multiplied by 100% [% crash reduction = 100% x (1-CMF), so if CMF = 0.48, a 52% reduction can be expected].

Table 1 - A summary of significant CMFs, with standard errors, estimated for the signalized intersection improvement projects

		All Intersections		3-Leg Intersections		4-Leg Intersections	
Crash Type	**Severity Level**	**CMF**	**SE**	**CMF**	**SE**	**CMF**	**SE**
Multi-Vehicle	**All**	0.81	0.05	0.73	0.10	0.83	0.05
	FI	0.67	0.08	0.42	0.13	0.72	0.09
Angle	**All**	0.63	0.06	0.59	0.16	0.64	0.07
	FI	0.59	0.10	0.31	0.18	0.64	0.12
	PDO	0.72	0.09	X	X	0.70	0.09
Rear End	**All**	X	X	X	X	1.26	0.12
	FI	X	X	0.42	0.17	X	X
	PDO	1.27	0.11	X	X	1.38	0.14

A benefit-cost ratio was also estimated for these intersection improvements. With the average improvement costing roughly $700,000 per intersection, the benefit-cost ratio was calculated to be 4.0 assuming a 20 year lifetime and a discount rate of 3%, showing a return of $4.00 in benefits from crash reduction for every $1 invested. Note that these benefits only include safety benefits and ignore operational benefits gained from these improvements.

Discussion

A review of the results in Table 1 show that for multi-vehicle and angle crashes of all severity levels, the crash reduction was similar for both intersection types. However, when appraising the fatal and injury results, the treatment was more effective for 3-leg intersections than for 4 –leg intersections (58% vs 28% for multi-vehicle FI crashes and 69% vs 36% for angle FI crashes), showing these treatments were more effective on 3-leg intersections than 4-leg intersections. The increase in rear end crashes should be noted, as these have a small offset on the benefits accrued from the crash reduction. These results, when taken into consideration with the benefit-cost ratio of 4.0[1], show these signalized intersection improvements provide economically viable safety benefits. Again, these results are indicative of intersection projects in which signal equipment and timing was upgraded, pedestrian, bicycle, and ADA accommodations were improved, pavement was resurfaced, and signage and pavement markings were upgraded.

[1] This memorandum has been updated to reflect newly adjusted comprehensive crash costs from FHWA for the state of Massachusetts.